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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

LUBRICANTS
1902—1952

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

The Freedom to Grow

HERE the venturer may start upon his dream with stars in his eyes — for all the small in this great land have the freedom to grow big.

The humblest vendor of today can become tomorrow's merchant prince and his cart a towering castle filled with wares of all the world.

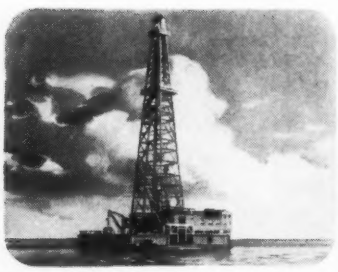
For the way was fashioned in the creed of men whose foresight is our fortune and whose concept of the American way was that the individual be free.

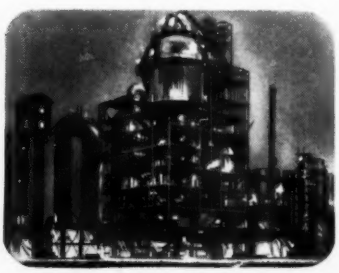
It is a concept that has made America's industries great and their greatness has made America strong.

Today, The Texas Company looks back fifty years upon a birthplace as primitive as the wagon of the vendor. Its forebears believed in freedom: the right to make their own choices, to run their own risks, to suffer of their own errors and to gather their own rewards.

Asking neither subsidy nor security, and knowing they would prosper only in proportion to the manner in which they served — a homely philosophy, but it is the bedrock of the American way, as solid as the ledge beneath the loam of our land.

For it has given America the most powerful sinews of all the nations of the world.





THESE PICTURES were merely dreams fifty years ago when The Texas Company was born.

Today, it is a leader in its field; in fact, the seventh largest among the great business organizations of America. Its rise is a moral in itself — an inspiration to all the young and small of business — kindling for the fires that light the eyes of every endeavoring American.

For how did it grow? Because it was born in this broad land where the lowliest may climb to the peak of ambition's loftiest pinnacle; and because Freedom of Enterprise stood by its side and whispered encouragement.

America's industries are symbols of America's strength; and like the biceps of the healthy and the strong, bespeak the wisdom of our way.

THE TEXAS COMPANY

Faithfully Yours for Fifty Years

TEXACO

1902-1952

Published by The Texas Company on its
FIFTIETH ANNIVERSARY

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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LUBRICANTS—1902-1952

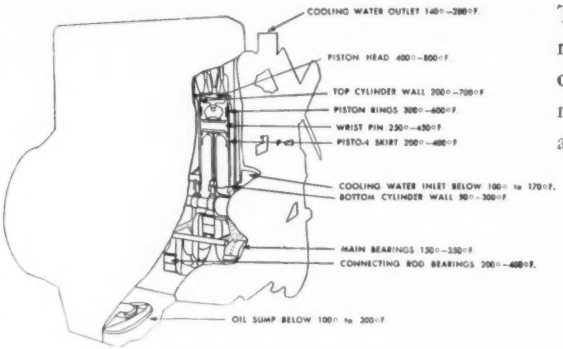
SUCCESSFUL completion on August 28, 1859 of the Drake well near Titusville, Pennsylvania at a depth of 69 feet and with a production of 25 barrels of crude oil daily is recognized as marking the beginning of the petroleum industry in this country. However, the industry as it is known today was dramatically ushered in January 10, 1901 with the most sensational oil well of history, the Lucas gusher, discovery well of the Spindletop Field. Flowing crude oil at the rate of 75,000 to 100,000 barrels daily, which was 50% of the total average daily production of the United States, Spindletop marked a new era in crude oil discovery. It was much more. Spindletop signaled the availability of petroleum products in abundant quantities. It started a shift in the center of the industry to the Southwest. It also signaled the dawn of an era which was to see petroleum become a major source of energy and the dominant source of lubricants; an era which was to see petroleum become intimately associated with the internal combustion engine, the automobile, the airplane, the diesel electric train, all of which followed and to a large measure were made possible by the abundance of petroleum products.

Providing a source of low cost lubricants to meet the requirements of all industries; e.g. iron, steel, the non-ferrous metals, railroads, textile, electrical, it was only a natural course for the petroleum industry to become closely allied to these other industries as well as those directly associated with the internal combustion engine. None could operate without petroleum products; conversely the petroleum industry depends on them for existence.

At the time of Spindletop petroleum products were few; kerosene the major product, gasoline, a few grades of lubricating oils and grease; refining procedures were relatively simple; crude oil movement was very limited. The transition to 1952 is one of contrasts whether one looks at the number of products, at product composition, at refining procedures and equipment, at test methods or at research. Entirely new utilization and products appear in the petrochemical field. Flexibility is the key word in crude transportation. In lubricants entirely new practices appear such as technical service, performance testing, field testing and packaging research; entirely new properties other than reduction of friction and wear between moving parts are commonplace.

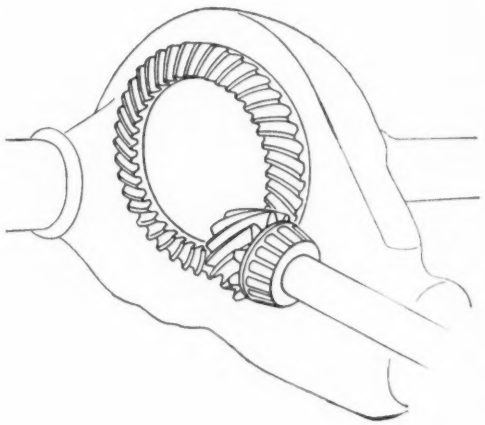
LUBRICANTS — 1902

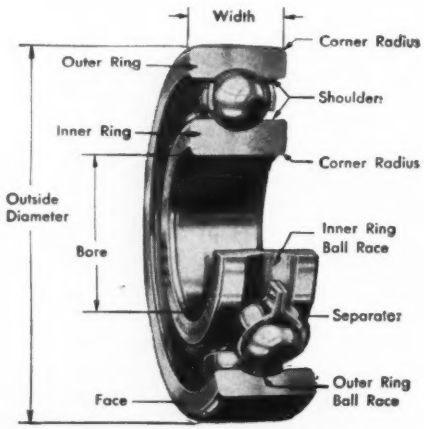
In 1902 lubricating oils were produced almost entirely from Pennsylvania crude. Two basic types of refined oil were manufactured, (1) a low viscosity neutral distillate stock and (2) a high viscosity bright stock. The former was produced from a shell vacuum steam distillation unit; wax was removed in frame and plate presses; filtration over bone char or bone black directly or following acid and caustic treating was practiced to improve color and odor. The production of a bright stock, so


COOLING WATER OUTLET 140°–200°F.
PISTON HEAD 600°–800°F.
TOP CYLINDER WALL 200°–700°F.
PISTON RINGS 300°–600°F.
WRIST PIN 230°–430°F.
PISTON SKIRT 200°–400°F.
COOLING WATER INLET BELOW 100° to 170°F.
BOTTOM CYLINDER WALL 90°–300°F.
MAIN BEARINGS 150°–350°F.
CONNECTING ROD BEARINGS 200°–400°F.
OIL SUMP BELOW 100° to 200°F.

The internal combustion engine imposing a wide range of temperatures and lubricating requirements on the oil has been a dominant factor in the developments of new refining processes and use of chemical addition agents.

The hypoid which develops a sliding motion between the teeth of the pinion and ring gear thus tending to rupture the lubricating film created the demand for the active EP type gear lubricant to provide adequate load carrying capacity.





The anti-friction bearing has played a significant role in directing the course of grease developments due to requirements of a buttery type grease with shear stability, oxidation resistance and capable of resisting the washing action of water.

The high speed Diesel with characteristic sooty combustion causing extensive soot contamination in the oil was critical to filter clogging and ring land area deposits. The detergent heavy duty type additive oil was a development to meet this situation.

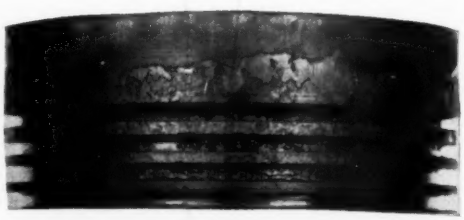


Figure 1 — Advances in the mechanical field which have been prominent in directing the course of lubricant developments.

named because it remained clear and translucent at ordinary temperatures, was a relatively recent innovation and was accomplished by filtering the Pennsylvania crude over bone char to remove asphaltic material; wax content was reduced by diluting the filtered oil with naphtha, cooling by natural means, and gravity settling; artificial refrigeration was to come later. Quality aspects were limited to viscosity, odor and color, the latter being an indication of the degree of removal of asphaltic material. The only function expected of lubricants was to reduce friction and wear between moving parts. Progress in standardization of test methods was hardly more than a vision. The influence of the internal combustion engine was non-existent. The diesel engine, the hypoid gear, the bi-metallic bearing were yet to come. Grease products were in their simplest form of a metal soap-thickened oil; most commonly the calcium or sodium base type of grease. Application was essentially for plain bearings; the role of antifriction bearings was to come later. Research was confined to the university laboratory; a petroleum research laboratory was unknown.

However, events were taking place which were to exert a profound influence on all phases of lubrication and which were to direct the course of and accelerate the rate of progress beyond the most visionary dreams. In 1902 two automobile records were established – New York to Boston (225 miles) in 15 hours and Toledo to New York (825 miles) in 16½ days. At Dayton, Ohio, two lads named Wright built a wind tunnel to experiment with wing shapes. They believed that they could bring to reality the age old dream of mechanical flight; successfully accomplished the following year. From the newly discovered Spindletop field a flood of crude oil was engulfing the petroleum industry. The stage was being set in which mechanical developments were to guide, accelerate and set the pace for developments in the lubricants and lubrication field.

LUBRICANTS – 1952

The transition in the field of lubricants from 1902 to 1952 is the product of step-by-step improvements punctuated at intervals by entirely new developments. Increasingly over this period, changes in a lubricant have come to involve not

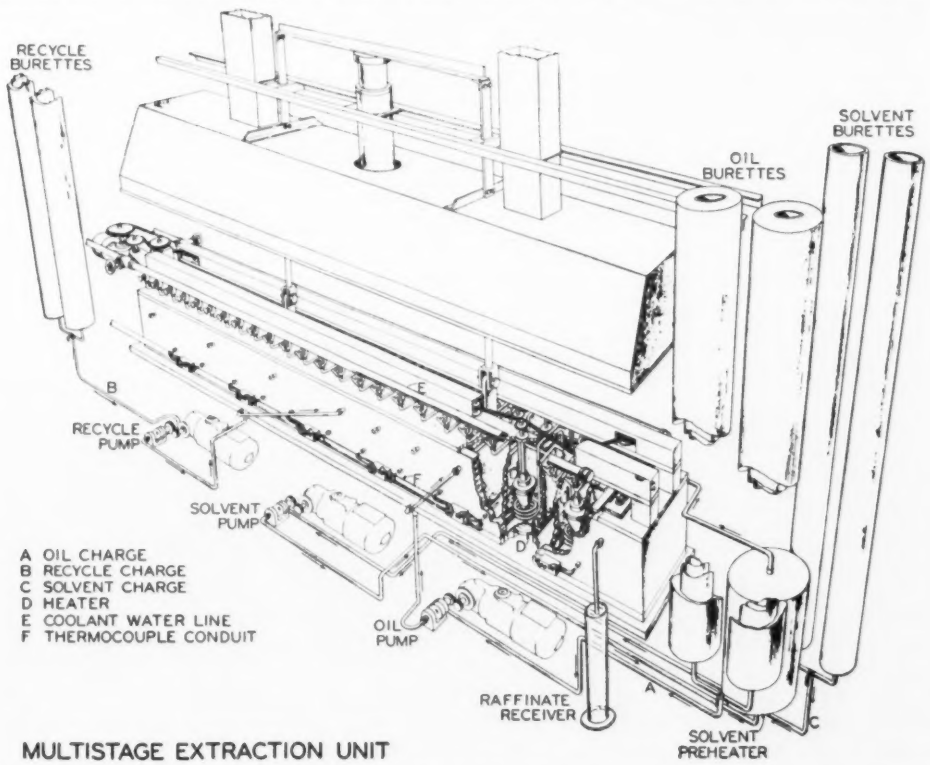


Figure 2 – A 24 stage counterflow extraction unit designed to operate with or without extract recycle or water rejection and to simulate at 1-3 qts./hr. charge rate the performance of refinery vertical counterflow towers. Units of this type are used in crude evaluation work and to obtain basic plant design data as well as fundamental extraction data.

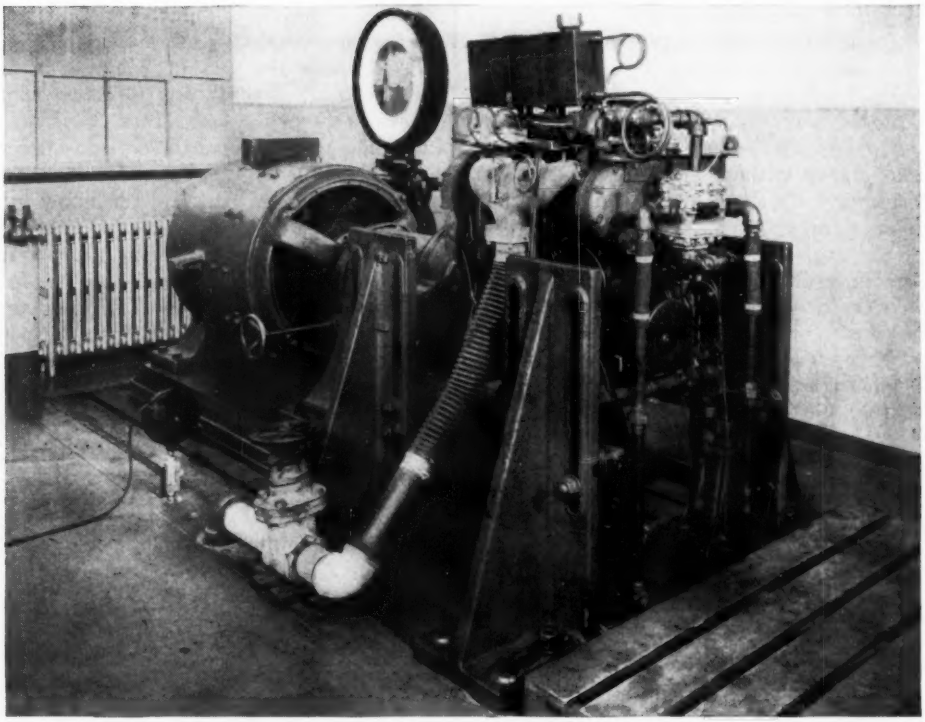


Figure 3 — A full scale 3-cylinder diesel engine on a laboratory test stand which is used both in evaluating the performance of base oils and in developing new types of additive oils for diesel service.

alone the refiner but also the equipment manufacturer and the user.

The refiner pictures lubricants from four basic angles:

1. Crude selection
2. Application of modern refining, compounding and packaging equipment
3. Use of chemical addition agents
4. The application of performance type evaluation methods.

The equipment manufacturer is vitally interested in knowing that satisfactory lubricants are available to the user.

The customer studies a lubricant as to:

1. Its ability to satisfy over long operating periods
2. Its ability to meet the requirements of the highest level of severity of service
3. Its ability to perform over a wide temperature range
4. Its ability to provide a variety of surface protective properties.

Thus, in contrast to the 1902 conception of a lubricant as a medium to reduce friction and wear between moving parts, *the 1952 lubricant is a versatile, multi-functional product* which must not only perform the primary functions of preventing friction and wear, but must commonly act as a heat transfer medium, as a protection against rust or extraneous corroding agents, as a scavenging medium for all types of contaminants, and as a sealing medium. These functions must be available over extreme conditions of temperature, speed, loading and operating time.

This transition of lubricants to a multi-functional performance status also has brought in its wake such developments as the widespread usage of performance evaluation testing, the resort to field testing when new products are introduced, and the technical service activities of the refiner.

CRUDE SELECTION

"Crude Selection" in relation to lubricating oil manufacture during the early part of this fifty year period had little significance due to the necessity of using crude oil sources most conveniently available to the refinery as charge stocks for all petroleum products. With the development of the sprawling network of crude oil pipeline transportation facilities and tanker fleets, a refinery no longer was limited to nearby crude oil sources. This made it practical to select crudes most suitable for certain types of lubricating oil manufacture on the basis of refining yield and quality character of the finished oil.

Today, as a result, "crude selection" is considered as the first step in lubricating oil manufacture. It starts with segregation in the producing field and continues with segregation through the pipelines to tank storage, right through to the final packaging operation. The advantages gained from such a crude segregation program are threefold.

1. Oils from certain crude sources may be superior for a given type of service
2. It is an important initial step in maintaining uniformity of quality
3. A maximum refining yield and refining economy are possible.

To exploit a program of crude selection and segregation requires that as each new oil field is discovered the crude oil therefrom must be given a screening evaluation as a potential lubricating oil source before it is routed to the refinery. Those crudes that show promise as to yield, quality, volume availability and refinery availability then are more thoroughly evaluated in pilot unit production. Such equipment as the box counterflow solvent refining unit as shown in Figure 2 is employed which when running on a six gallons per day charge rate will show refining characteristics to be expected in a plant unit of 5,000 bbls./day capacity.

The performance quality of the refined oil in this secondary stage of evaluation is studied in major lubrication services such as automotive engines or in even more critical operation such as diesel and aircraft engines. Refer Figures 3 and 4.

Refining of Lubricating Oils

With even the best selected crude only part of the hydrocarbon molecules in the required viscosity range are of the proper chemical structure to meet modern lubricating oil demands. Accordingly improvement in refining methods over the years has been directed essentially towards increasing the selectivity and efficiency of removing those molecules least suitable for lubricant purposes.

Today the refiner has at his command a flexible

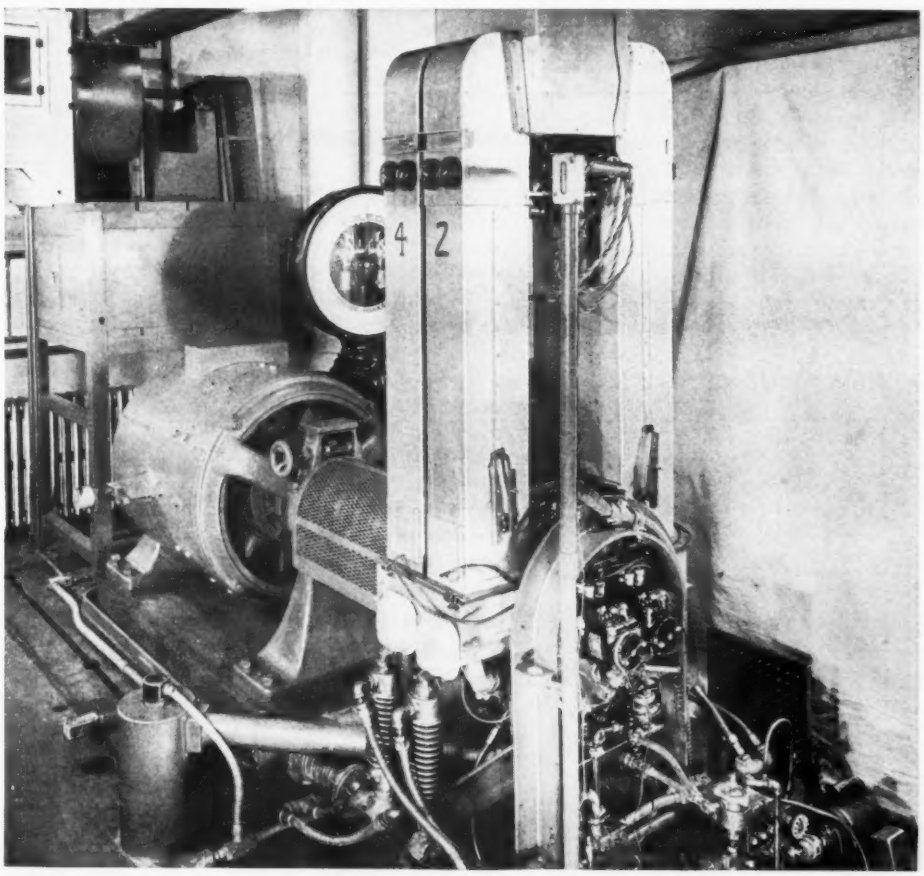


Figure 4 — A small 4-cylinder aircraft engine on a laboratory test stand is employed in evaluating new crude sources for aircraft oil use. Engine is also used in development of additive oils.

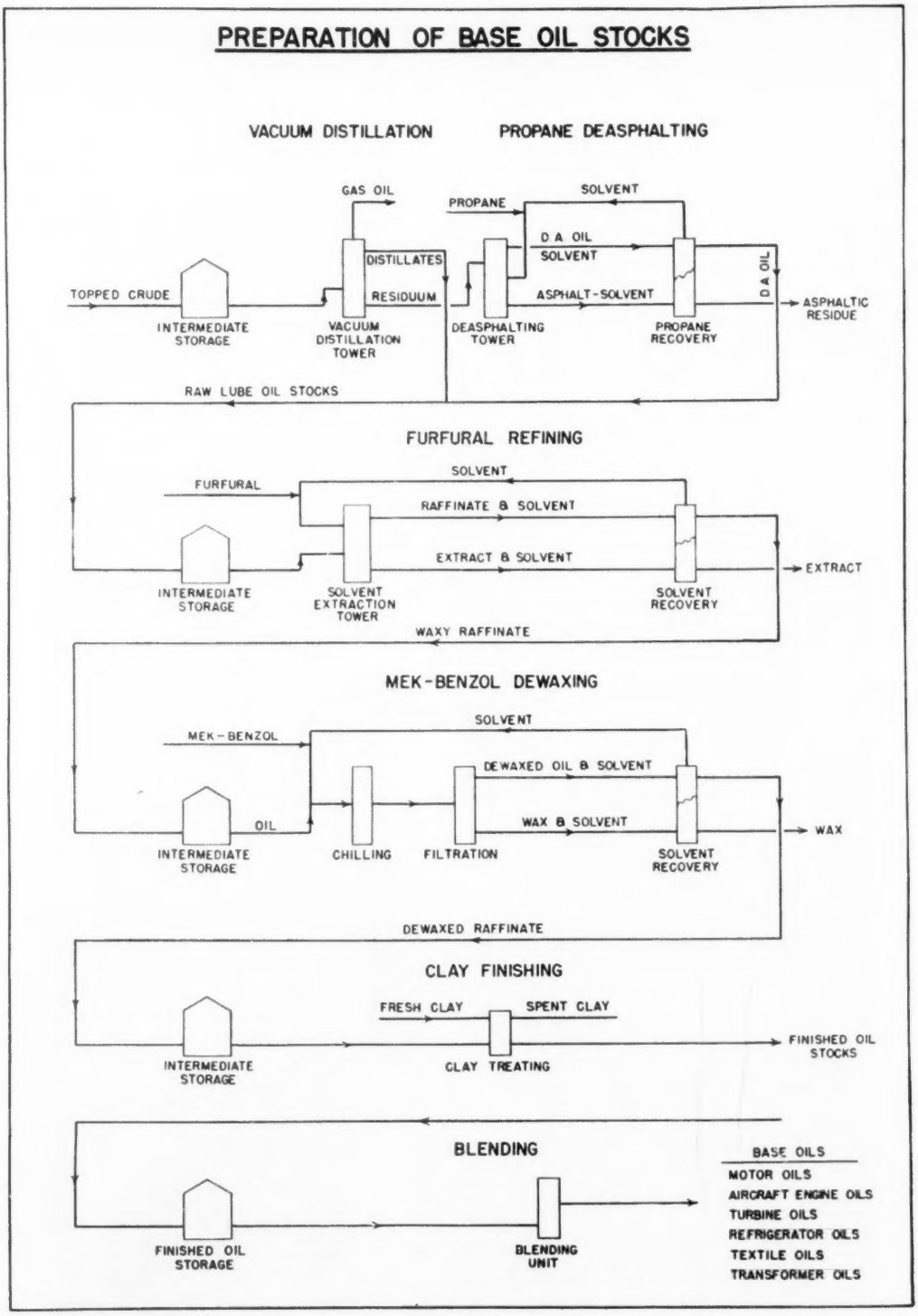


Figure 5 — Outline of steps and processes in refining of lubricating oil. Based on chart from "Modern Manufacture of Lubricating Oils" by E. R. Smoley and D. Fulton, The Lummus Co. Published in Petroleum Processing, August 1947.

and imposing array of refining procedures including high vacuum pipestill distillation, bubble tower fractionation, efficient heat exchanger systems, solvent dewaxing, solvent refining, deasphalting and a choice of finishing steps (clay contacting, acid treating, percolation or caustic washing) all working to produce a uniform high quality oil from a wide range of crude types.

The development of this flexible and efficient group of refining methods has been one of slow improvement although accelerated at intervals by introduction of entirely new processes, some of which have since become landmarks in refining history. The construction of the first solvent dewaxing plant employing acetone-benzol in 1927 is one such process. This replaced frame and plate presses and centrifuge processes which were subject to sharp limitations of being restricted to crystalline and amorphous wax stocks respectively.

The acetone-benzol process was adaptable to all types of charge stocks and capable of producing oils of zero or lower pour test. Propane solvent type dewaxing plants were subsequently developed and methyl ethyl ketone replaced acetone, but of outstanding significance was the fact that the new process placed the refiner in command of the low pour oil requirement created by the automobile industry which demanded oils that would flow more readily in winter.

As trends in automotive engine design progressed to include higher engine speeds, greater power, increased compression ratio, higher bearing pressures and higher oil system temperatures, the petroleum industry in turn had to study oil properties which until then had not seemed to be too important, i.e., oxidation stability with the associated property of deposit formation, and rate of change of viscosity with temperature. Of significant influence at this time was the announcement of the viscosity-index chart as a convenient though empirical yardstick for expressing viscosity-temperature relationships which served to dramatize the struggle which had been going on between paraffin base oils and the more easily made and lower cost naphthene oils from asphalt base crudes.

Against this background solvent extraction was developed through research and introduced as a new refining tool which in one operation removed by selective solubility those types of hydrocarbon molecules which had the poorest viscosity-temperature properties and the greatest tendency to form oil insoluble material and deposits under oxidizing conditions. Although it was a totally new process requiring entirely new equipment, the application of solvent extraction to oil refining mushroomed in growth during the years 1930-1934 with the first phenol plant in 1930, the first furfural plant in 1933 and the first duo-sol unit in 1934.

The revolution in lubricating oil refining which started with the introduction of the acetone-benzol dewaxing process in 1927 followed by solvent extraction in 1930 was completed with the introduction of the propane deasphalting process. This made possible the production of a bright stock from any lubricating oil crude source by treating a residuum with propane and thereby removing the high molecular weight most asphalt-like material which is totally unsuited for lubricant purposes.

These new refining processes outlined in Figure 5, all operating as continuous processes, controlled by modern instrumentation and capable of high daily charge rates, in a sense may be considered comparable to the development of the assembly line production technique in the automotive industry. For the first time the refiner was in a position to produce an oil of uniform quality and in a volume required for national distribution. Some condensed refining data are illustrated in Table I.

Paralleling the revolution in new refining processes was the development of new tools for maintaining a uniform quality of the refined oil. Through the intermediate stages of manufacture, quality controls are based primarily on physical data such as gravity, viscosity, viscosity index, or refractive index. The plant control viscosity measurements are made using a continuous recording viscosimeter on the deasphalted oil stream of the propane deasphalting plant and on the wax distillate streams of vacuum pipe stills. With the finished oil, in addition to physical data, bench performance data are obtained such as in the Toettcher Oxida-

Figure 6 — Typical appearance of grease structure when studied under the electron microscope.

TABLE I

FURFURAL REFINING OF FRACTIONS FROM MID-CONTINENT CRUDE

	Medium Distillate			*Heavy Distillate*			*Deasphalted Short Residuum*		
	Dewaxed Charge	*Dewaxed Raffinate*	*Extract*	*Dewaxed Charge*	*Dewaxed Raffinate*	*Extract*	*Dewaxed Charge*	*Dewaxed Raffinate*	*Extract*
Gravity, °API	22.6	29.5	11.1	20.9	28.9	12.0	19.7	26.3	14.2
Saybolt Universal Viscosity									
at 100°F.	480.5	249.3		1614	567.9		9358	2929	
at 210°F.	55.3	49.3	88.1	89.7	64.5	186.7	254	161.8	387
Viscosity Index	52.3	96.9		43.5	96.3		63.4	92.8	
NPA Color	8	3½		8+	3+				
Carbon Residue	0.28	0.02		1.05	0.02		2.4	0.44	

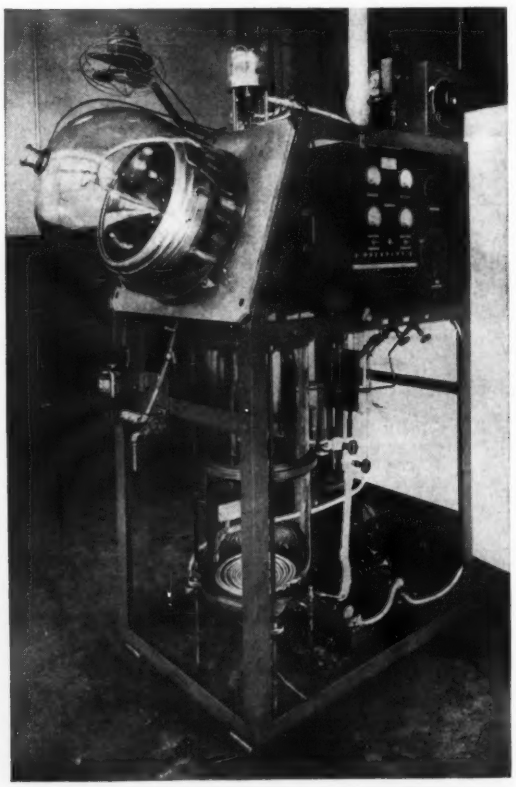


Figure 7 — This type of molecular still is applied in fundamental studies to obtain a fractionation of the highest viscosity grades of lubricating to obtain data of type shown in Figure 8.

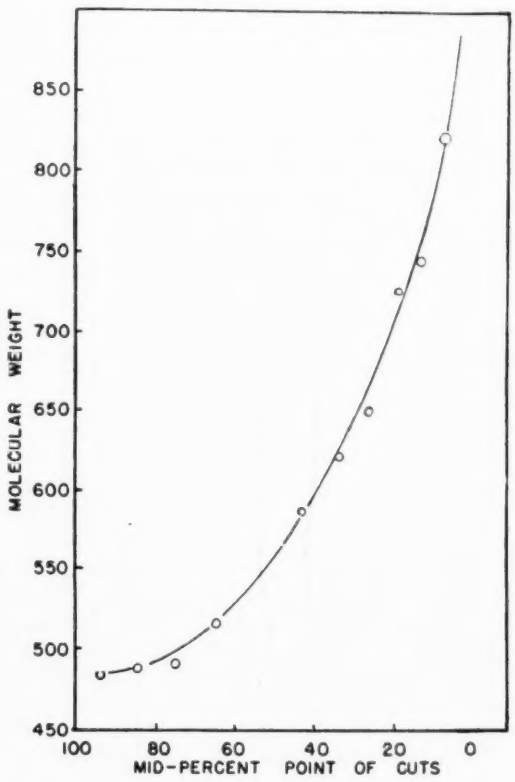


Figure 8 — Typical curve as referred to in connection with Fig. 7.

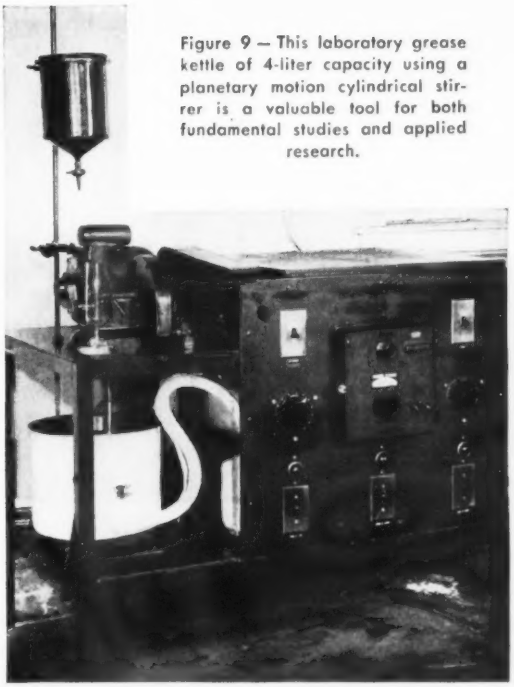


Figure 9 — This laboratory grease kettle of 4-liter capacity using a planetary motion cylindrical stirrer is a valuable tool for both fundamental studies and applied research.

tion and Deposit Test or the ASTM Turbine Oil Oxidation Test; or, in the case of crankcase oils full scale engine tests on spot samples (Figure 3).

GREASES — 1902-1952

In the field of grease manufacture there is some outward resemblance in the major volume of 1952 products to those produced in 1902 since the basic building blocks of sodium or calcium soap and oil are still used. However, significant advances have been made in equipment design, in compounding procedures, in uniformity, in new physical properties, complexity of composition, and concepts of composition as prevail today.

Equipment advances include steam heated high temperature vessels, pressure kettles, milling or homogenizing units, improved mixing, controlled cooling, and continuous process units. With these improved tools and with the results of fundamental studies there has been a rapid shift from dependence on art in grease making to reliance on technical knowledge. This is illustrated by the range of physical properties it is possible to create in a sodium soap grease by changes of manufacturing procedure whereby this type grease (which is normally fibrous in texture) can be made fibrous with long fiber, fibrous with short fiber, ropy, semi-buttery or buttery.

A new look to the old building blocks was imparted by the introduction of mixed base greases, in order to obtain the most desirable properties of the respective soap base constituents. For example a mixture of sodium and calcium soaps produce a smooth buttery grease especially suited to anti-friction bearings.

The manufacture of a wide temperature range ball and roller bearing grease possessing a melting point above 500°F. and suitable torque characteristics at —30°F. is an example, where new equipment, new procedures, a complexity of building blocks and advanced technical knowledge are required.

In order to meet the demands imposed by low temperature conditions existing in instrument and control bearings of aircraft, entirely new building blocks have been used. Here lithium soaps of special fatty materials show improvement in physical properties with respect to melting point, adhesiveness, resistance to shear breakdown and the washing action of water as well as utility at both ends of the temperature scale. The use of synthetic oil (such as the di-sec.-amyl sebacate) in greases of the lithium soap type is a milestone in grease technology, and provides a lubricant

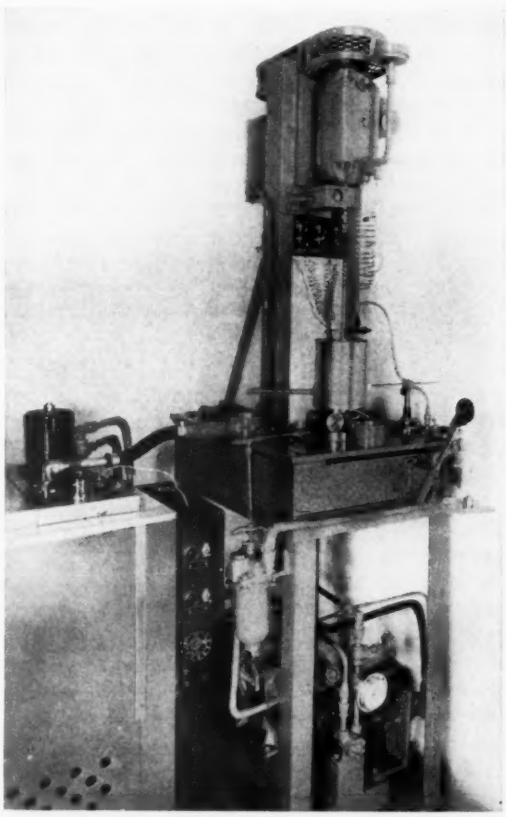


Figure 10 — This high rate of shear rotational viscometer is adaptable to studying the shear behavior of non-Newtonian lubricants at closely controlled temperatures, an essential control at high shear rates.

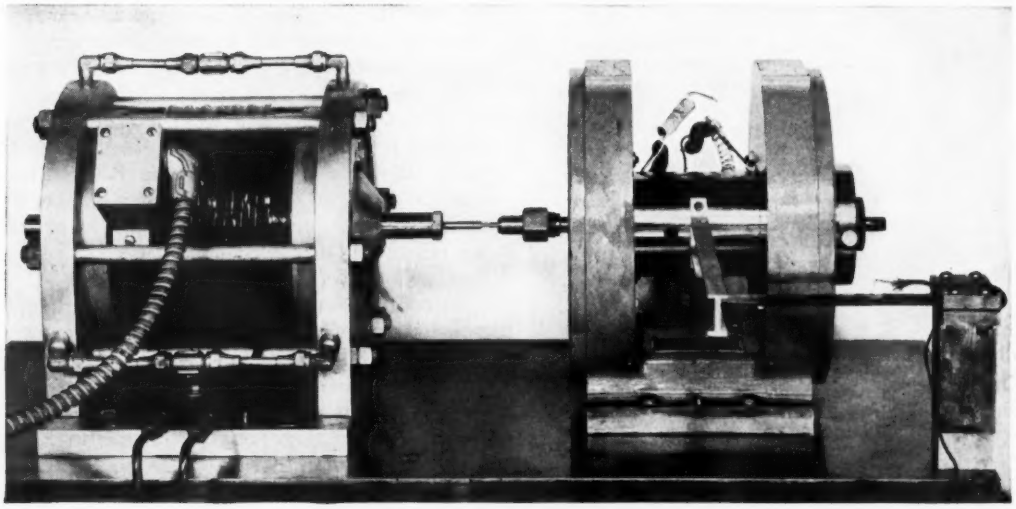


Figure 11 — Equipment designed to make fundamental studies of grease lubrication at rotative speeds up to 36,000; showing 7 HP., 36,000 r.p.m. motor connected with a "necked down" drive shaft with grease test unit equipped with temperature control and torque measuring device.

especially suited to extremes of temperature change and where a low of — 100°F. may be encountered.

The last few years of this fifty-year period have witnessed an accelerating struggle to increase the upper limiting temperature of grease application without impairing low temperature performance. Requirements of equipment for the armed services have played a dominant role in this struggle as reflected in the specification MIL-L-15719A requiring performance over a temperature range of 0°F. to +300°F. Contributing to attaining this goal have been the use of selected refined petroleum oils, oxidation inhibitors, selected metal soaps, synthetic oil and most recently the use of non-metal soap thickeners of which copper phthalocyanine is an example. The combination of synthetic oil and copper phthalocyanine represents another milestone in grease development which marks the complete transition from the 1902 product as simple metal soap thickened mineral oil to the 1952 product as a non-metal soap thickened non-petroleum synthetic oil.

Despite the tremendous strides which have been made towards increasing the versatile character of grease lubricants, the scope of applications has increased at an even greater pace giving rise to specialty greases for specific applications such as track roll lubricant, steering gear lubricant, or rail and flange lubricant.

Indications of trends to designate products suitable for a wide range of applications is reflected in Army Ordnance Specification MIL-G-10924 (see Table II) for lubrication of military vehicles under all climatic conditions, and MIL-G-7118 an EP type low temperature grease suitable for gears and actuator screws as well as anti-friction bearings. The trend to use centralized lubrication systems as in steel mills also requires a grease adaptable to a wide range of conditions.

The maintenance of uniform quality in grease lubricants starts with a rigid control of the uniformity of the basic ingredients accomplished by setting up specification tests; continues with a close control on manufacturing procedure; and is completed by a careful check on the final product. Physical and chemical tests, and functional bench performance tests such as the salt water rusting test, the wheel bearing test (Figure 15) or the Norma-Hoffman Oxidation Test are applied to the finished grease.

ADDITION AGENTS

In many applications and types of service the best refined mineral oil or the best soap-oil type grease does not completely satisfy the requirements of equipment or service. To meet this situation the refiner has resorted to the use of a carefully selected group of chemical addition agents which are compounded with the base oil or grease stocks. These chemical addition agents for the most part serve to enhance the natural properties of the oil or grease and make it more durable. The type and amount of addition agent is determined by the application and severity level of the service. In a steam turbine oil low concentrations of an oxidation inhibitor, a rust inhibitor, and an antifoam agent are adequate to satisfy the most severe service. On the other hand gear oils for severe service require the intricate composition and high concentration of addition agents which make up the

TABLE II

SPECIFICATION MIL-G-10924

Worked Penetration	350 max.
Drop. Point, °F.	300 min.
Evaporation Loss (22 hrs. at 210°F., % Loss)	12.0 max.
Oil bleeding (50 hrs. at 160°F.) % Loss	4.0 max.
Bomb Copper Corrosion (20 hrs. at 210°F.)	Must pass
Salt Spray, (100 hrs.)	No rust
Wheel Brg. Test (2-108B) leakage—gms.	10 max.
Norma Hoffman Oxidation, psi. drop	5 lbs. max. 100 hrs. for 400 hrs.

Universal Gear Lubricant covered by Military Specification MIL-L-2105 containing lead, chlorine, sulfur and phosphorous type addition agents as well as a pour depressant, a viscosity index improver, and an anti-foam agent.

In crankcase oils, addition agents such as pour depressants and viscosity index improvers are used to impart greater oxidation stability, assist in controlling engine deposits, provide protection against corrosive wear and rust and widen the temperature application range. In most of these applications there are limitations on the type of addition agent that can be used; e.g., in steam turbine oils a rust or oxidation inhibitor which impairs good water separating properties is avoided.

The application of addition agents to grease products has resulted in a galaxy of modifying agents which increase not only oxidation stability, corrosion protection, rust protection, and load carrying property, but also melting points, tackiness, water resistance and foam resistance. The physical character of the grease also may be controlled by the proper selection of an addition agent, for example, a calcium soap grease which would have a typical buttery texture without addition agents may be changed to a tacky, stringy product.

SYNTHETIC OILS

The attention given to the role of synthetic fluids in the lubricants picture at the end of this fifty-year period marks a significant milestone. Present usage of synthetic oil-base lubricants is limited to small volume specialty products such as in greases for aircraft control and instrument bearings, instrument oil, turbo-jet engine oils, or hydraulic oils. However, these products represent a significant trend in the development of lubricants possessing certain performance qualities

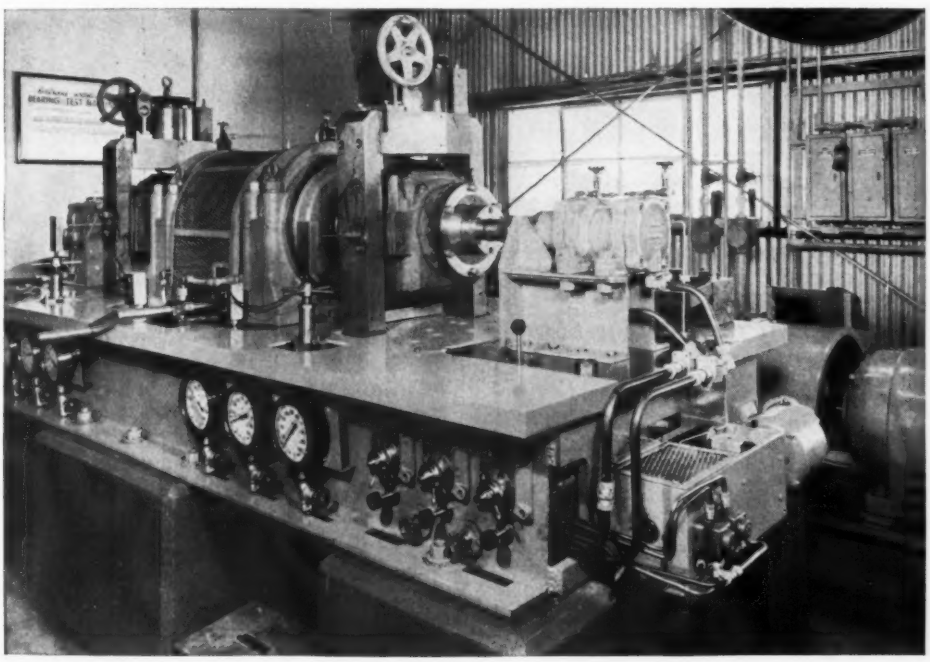


Figure 12 — This versatile seven ton bearing tester requiring a 75 HP. motor represents an advanced step in the development of specialized railroad lubricants.

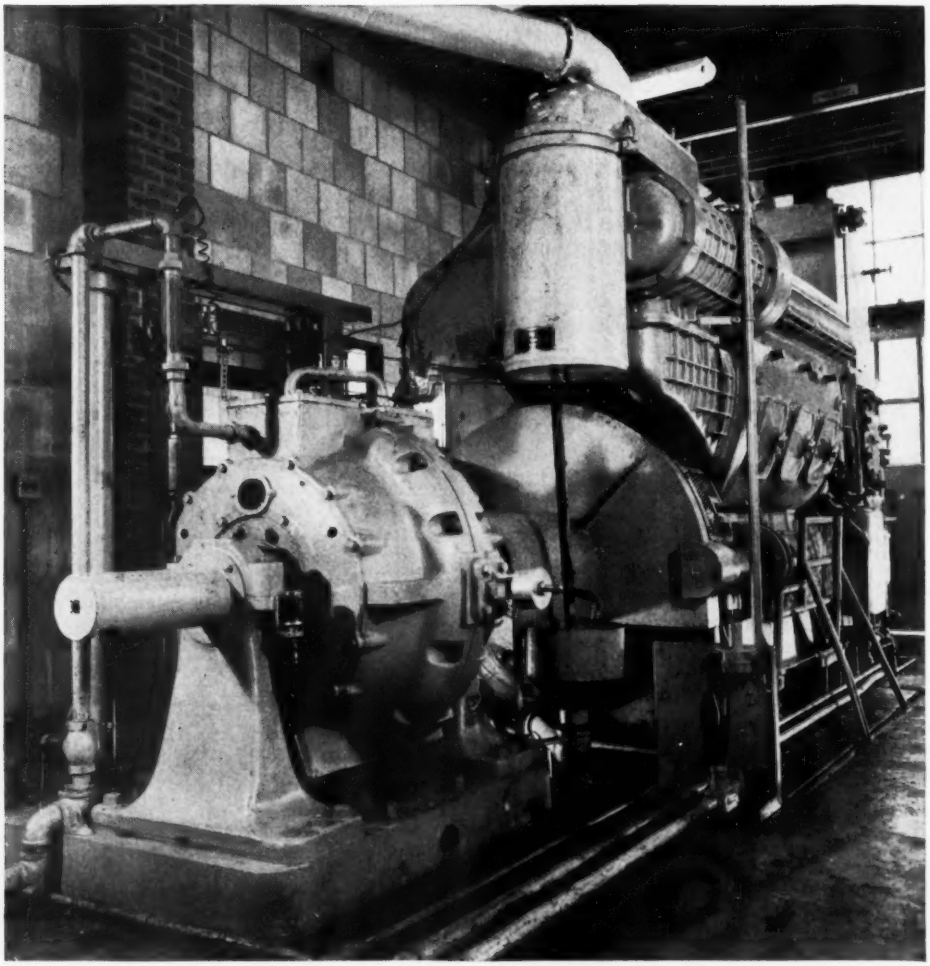


Figure 13 — A six-cylinder 600 HP. railway diesel engine setup as used in laboratory evaluation work on fuels and lubricants.

which cannot be attained by use of naturally occurring petroleum material. Thus synthetic oils of the diester type or the polyether type occupy a small but strategic position in the current lubricant picture.

RESEARCH

No other aspect of lubrication developments has undergone greater change over this fifty year period than that of research. At the time of the Spindletop field discovery lubrication research was carried on in the university laboratory and was in that richly productive stage of developing the basic concepts, establishing the hydrodynamic theory of fluid film lubrication, the relationship of viscosity to friction, and increased precision in measuring viscosity. The intervening years have brought into prominence industrial research facilities and totally new types of research.

Boundary lubrication and surface phenomena are major subjects of both fundamental and applied research; the more important aspect of which concern boundary friction, wear prevention, corrosion and its prevention, load carrying or EP property, surface deactivation of pro-oxidants, foaming, emulsification and dispersant action. The molecular type composition of refined oil and improved selectivity of refining processes; the physical structure of grease and the effect of both process variables and composition on properties; the search for new addition agents and the mechanism of their action are all prominent in research at the end of this fifty-year period. Thus the roots of lubrication progress are in the research laboratories of industry and the universities.

Of all changes over this fifty-year period the tools for research hold a unique position. With

totally new tools available, new vistas of knowledge have been glimpsed and new horizons of exploration have been opened. They encompass the spectacular possibilities of the electron microscope employing a stream of electrons instead of a light source and a magnetic field to focus the electron beam in place of lenses as in light microscopy. Magnifications of 45,000 are possible; in other words, if a city block could be reduced in size as to be barely visible, then a light-ray microscope could pick out a card table set on the original city block while the electron microscope could pick out a small marble placed on this card table. The application of the electron microscope to the study of grease structure is shown in Figure 6. Applications to a study of the size of soot particles in used diesel oils have also been made to indicate the action of dispersant addition agents.

The molecular still (Figure 7) is another device for peering more minutely into the composition of the least volatile component of lubricating oil by making possible non-destructive distillation which is accomplished by causing a thin film of oil to move very rapidly across a heated whirling rotor in an evacuated bell jar such that the exposure time is only a fraction of a second.

Any attempt at a listing of modern research tools less spectacular but equally significant in guiding lubricants research would be tiresomely long. Typical examples, however, are the rather obscure but important tools such as the small grease kettle (Figure 9) designed to duplicate on a one pound scale the product of a 50,000 lb. batch plant equipment, or the MacCoull oxidation and corrosion testing unit designed to simulate the effect on oil exposed in the crankcase of an engine in truck and bus service. The latter test is used for screening addition agents considered for heavy duty motor and diesel oils.

The high shear rate viscometer of Figure 10 was developed to study the non-Newtonion flow properties of fluid lubricants under shear rates up to 1,000,000 reciprocal seconds and is also adaptable to study of shear stability of grease. Such shear studies have important applications in the development of grease for high speed anti-friction bearings or in the use of polymeric addition agents of viscosity index improver type in crankcase oils as well as yielding data of a fundamental nature.

Looking forward to a continuation of the trend to increased spindle speeds the ultra high speed bearing test unit shown in Figure 11 providing for speeds up to 36,000 r.p.m. was developed to obtain fundamental data pertaining to both bearing design and the effectiveness of grease as a lubricant for anti-friction bearings at those high rotative speeds; more recently research envisions equipment to run up to 100,000 r.p.m.

A new phase of lubricant service developed with the trend in railway operations to replace plain bearings on locomotive journals and on passenger and freight cars with heavy duty roller bearings. The need developed for a laboratory machine to develop lubricants for this service. The Railway Journal Bearing Lubricant Test Machine in Figure 12 was designed through research to simulate steady car loads and shock loads, both vertical and horizontal, as encountered in service operation at speeds up to 100 miles per hour.

In developing better additive crankcase oils much valuable screening information can be obtained in bench tests developed through research. However, performance in the engine is required for the final answer. This has brought into everyday use a wide variety of special engine testing equipment ranging in size from a single cylinder 3 HP gasoline engine setup to the six-cylinder 600 HP railway diesel engine setup in Figure 13. Other special engine setups are required to study such problems as low temperature corrosive wear, valve guide corrosion, valve burning or ring sticking.

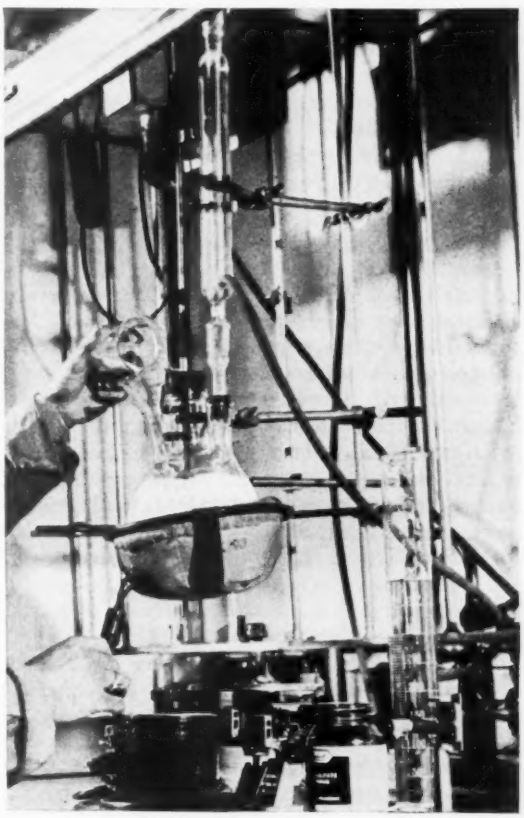


Figure 14 — The important role of addition agents and synthetic oil has given organic chemistry an important niche in the lubricant picture.

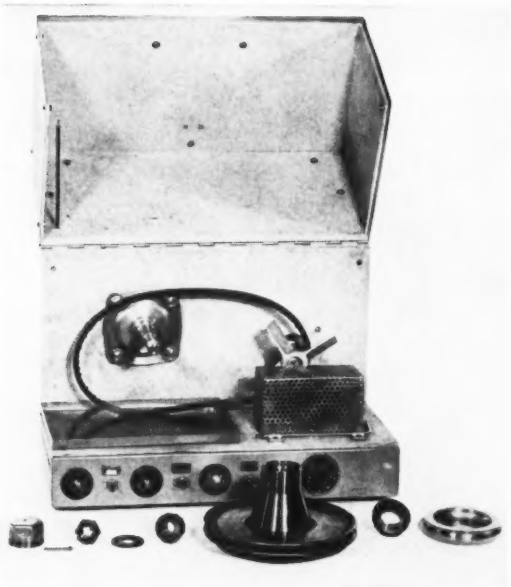


Figure 15 — The ASTM-CRC wheel bearing tester as used in quality control testing of grease lubricants.

The rise in importance of the chemical addition agent and the introduction of synthetic oil have brought the research tools of organic chemistry to the forefront of lubrication progress and such organic synthesis setups as that of Figure 14 are as much a part of present day lubrication research as a dewaxing or solvent refining unit, or a grease-making kettle.

QUALITY CONTROL

Along with the development of lubricants for specific functional purposes for long or lifetime operation such as in sealed bearings or for high level severity of service conditions, there has been a parallel trend to use performance tests as a measure of quality. This is a basic function of the refiner and requires research to develop suitable methods which can be applied to routine daily use. Such test methods are commonly the result of cooperative research work between the refiner and the customer. Performance tests of this nature are represented by the ASTM Rusting Test which is used not only as a control of quality of steam turbine oils at point of manufacture but also as a research tool to find new chemical compounds that will give better protection against rusting of ferrous parts. The ASTM-CRC wheel bearing grease testing equipment shown in Figure 15 is another illustration.

In the field of crankcase oils a group of standardized CRC L-engine test procedures developed under the auspices of the Coordinating Research Council jointly sponsored by the Society of Automotive Engineers and the American Petroleum Institute have been incorporated in U.S. Army Specification for heavy duty oil.

With the E.P. type gear oils for truck and bus service one of the extreme pressure testing machines sketched in principle in Figure 16 will be used.

This trend to place reliance on performance type of testing is a product of the multi-functional character of modern lubricating products.

Quality control also requires a check on composition where it is necessary to know that certain fundamental building blocks are present, in other words to let the atoms call "present." Chemical methods are the traditional tools, but physical methods based on emission spectroscopy, flame photometry, and the polarograph have become commonplace and accomplish in minutes the results which would require hours or days by chemical methods.

The least spectacular and least recognized major development of this fifty-year period is the standardization of tests and methods. Guided industry-

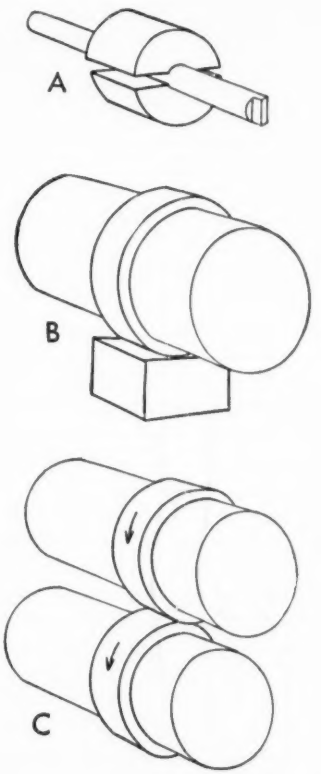


Figure 16 — Diagrammatic sketch illustrating the principle of operation of A, Almen, B, Timken, and C, SAE, Extreme Pressure Lubricant Testing Machines. In all three cases the rubbing surfaces are steel on steel.

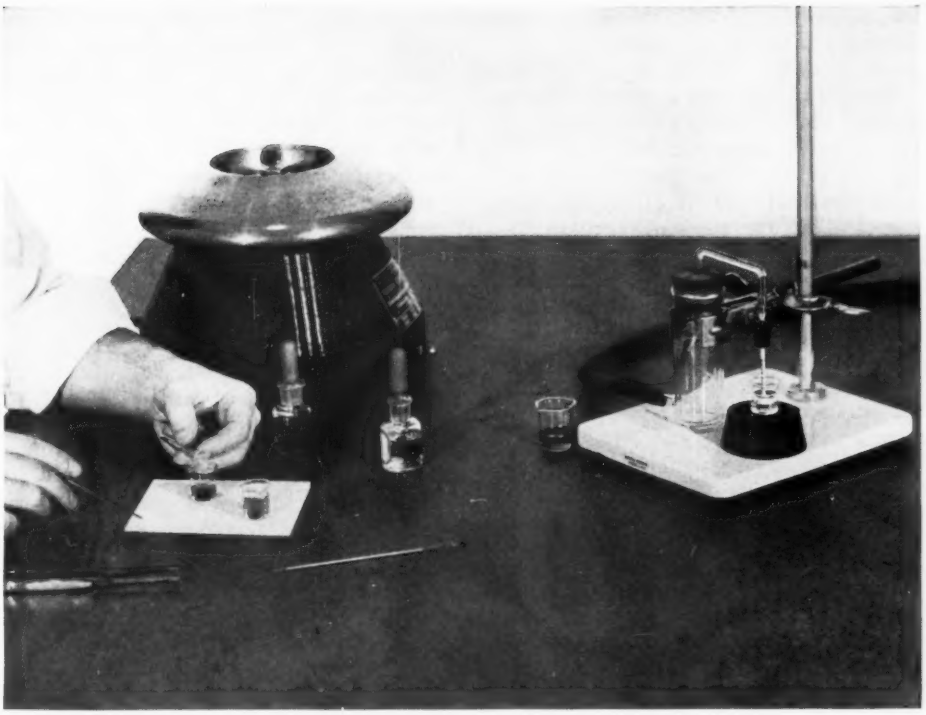


Figure 17 — In Technical Service work extremely small samples of sludge, bearing scrapings or used oil are commonly only available. Here is shown a miniature centrifuge as used in microchemistry to separate particles impractical to filter.

wise by ASTM Committee D-2 on Petroleum Products and Lubricants and within the industry by the Standardization Departments, the uniformity and accuracy of test data are given a maximum of insurance which is a pillar on which research product development and quality control are based.

FIELD TESTING

The practice of field testing when new lubricants are introduced, unknown at the start of this period and with no sharp inception date, has a significant niche in today's picture as a final insurance of the quality of new products. While performance quality can be built into lubricants in the research laboratory with a maximum of assurance that these same qualities will be reflected in field service, the refiner in 1952 is not satisfied until closely observed actual field performance is available. Thus, before one well known branded motor oil was introduced to the public over 1,000,000 miles of observed field testing had been completed. At the end of the more severe phases of this testing program such as the 20,000 mile high speed passenger car fleet road test, each engine was disassembled in the laboratory overhaul shops where all parts were rated for cleanliness and wear and the used oil thoroughly examined.

With many types of lubricants field testing is carried out in cooperation with a customer. For example in the development of an additive type aircraft engine oil the experimental oil was placed in one of four engines on four different planes of a major airline. The performance was followed closely by technical representatives of the oil company, the airline, the engine manufacturer and the Civil Aeronautics Authority. With lubricants developed specifically to meet a government specification, field testing is usually carried out cooperatively with the government agency involved. The results of these field tests are of value not only to confirm the quality of the product and to guide research in development of further improved lubricants, but to insure that no undesirable property will develop that could not be foreseen in bench and laboratory performance testing.

TECHNICAL SERVICE

The successful lubrication of precision built, high efficiency, high power capacity equipment requires that the lubricant be properly selected and properly applied. The importance of selection and application formed the basis of the idea of technical service from the refiner to the customer which was crystallized in the founding in 1911 of "LU-

BRICATION", as a technical publication devoted to the selection and use of lubricants.

Unknown in 1902 and in its earliest form merely a sharing of experience between salesmen or engineering representatives of the refiner with the customer, technical service has grown into a well integrated phase of the petroleum industry, staffed with personnel who are highly trained not only in mechanical and automotive engineering, but also in chemistry, physics, colloids, photography, metallography and microscopy. Practical experience and technical training are now backed with chemical and mechanical testing facilities.

Activities are widely varied in nature. Trained personnel maintain active contacts with engine and machinery manufacturers as well as operators. At the same time the Analytical and Testing Department will be analyzing by chemical and physical methods samples submitted from the field. These samples may include used oils, combustion chamber deposits, crankcase sludge, or scrapings of grease from an anti-friction bearing, for determination of the presence and nature of any foreign contaminants or extent of lubricant deterioration. In such work micro-analytical techniques have been highly developed. (See Figure 17.)

In the mechanical laboratories the list of parts studied reads like a parts list for an overhaul shop, i.e., valves, alternator bearings, pistons and rings, wheel bearings, spark plugs, cylinder heads, pinion gear bushings, oil screens, link rods, cams, or a watch balance wheel. Comprehensive mechanical studies are made on operational problems as valve failures, piston burning, bearing failures, gear tooth scuffing, to name only a few.

Conferences are held at periodic intervals at which engineers from the operating units and the equipment manufacturer sit down with the technical service engineer and chemist and "let down their hair" so to speak to discuss subjects and problems of mutual interest. Individual technical service representatives with wide lubricant application experience discuss with equipment manufacturers complete lubrication charts for new equipment developments. In recommending suitable products for specific applications it may be necessary to conduct work on an actual unit. For example, several years ago an electric propeller was tested in a cold room to note the effects of lubricants on the rate of change of pitch. Based on these tests, oils and greases were recommended which enabled operation of the propeller mechanism at extremely cold conditions.

Another type of function is the maintenance of contacts with all government agencies dealing with lubricant testing, evaluation or specification. Other functions include the planning and supervision of field testing on new lubrication products developed by the research group; the making of surveys on competitive products; the correlation of inter-company tests when engine or mechanical testing is involved; or cooperative work with the customer in determining maximum oil drain period based on used oil condition.

PACKAGING

In its early form packaging of lubricants was dictated only by convenience of distribution. Today packaging serves also as a protection of product quality and as a convenience in handling, storing and dispensing. At times a product composition as in the case of heavy duty gear lubricants requires special considerations as to type of package. The use of the most economical type of container is also a factor, as well as using a minimum of raw materials such as tin which would be in critical supply in case of a national emergency. As a net result at the end of this fifty-year period packaging research has taken a permanent niche in the total lubricant picture.

CONCLUSION

The discovery of the Spindletop field signaled a new era in the petroleum industry, an era of rapid advances in the technology of lubricants and lubrication. Such advances have made commonplace, lubricants capable of a breadth and degree of protection to equipment not visioned fifty years ago.

Fundamental and applied research in the broad field of lubricants and lubrication and the availability of new tools of research have played a guiding role for these advances in product quality. In addition a vast storehouse of knowledge has been made accessible to guide the proper selection and correct application of the high quality products available. An increasingly significant contribution to this rapidly advancing front in the technology of lubricants has resulted from the cooperation and better understanding among lubricant supplier, equipment manufacturer and consumer. With the exciting trend towards increasing complexity of lubrication requirements, the future places a high responsibility on research and on industry cooperation to insure the availability of the proper types of lubricants.

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